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CABLING AND CONNECTORS TECHNOLOGY WORKING GROUP REPORT

(IDA/OSD R&M STUDY)

J. W. Bird
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August 1983

The views expressed within this document are those of the working group only. Publication of this document does not indicate endorsement by IDA, its staff, or its sponsoring agencies.

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INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

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This document records the activities and presents the findings of the Cabling and Connectors Technology Working Group, part of the IDA/OSD Reliability and Maintainability Study conducted during the period from July 1982 through August 1983.

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(IDA/OSD R&M STUDY)

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Martin Marietta Aerospace
Working Group Chairman

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1801 N. Beauregard Street, Alexandria, Virginia 22311

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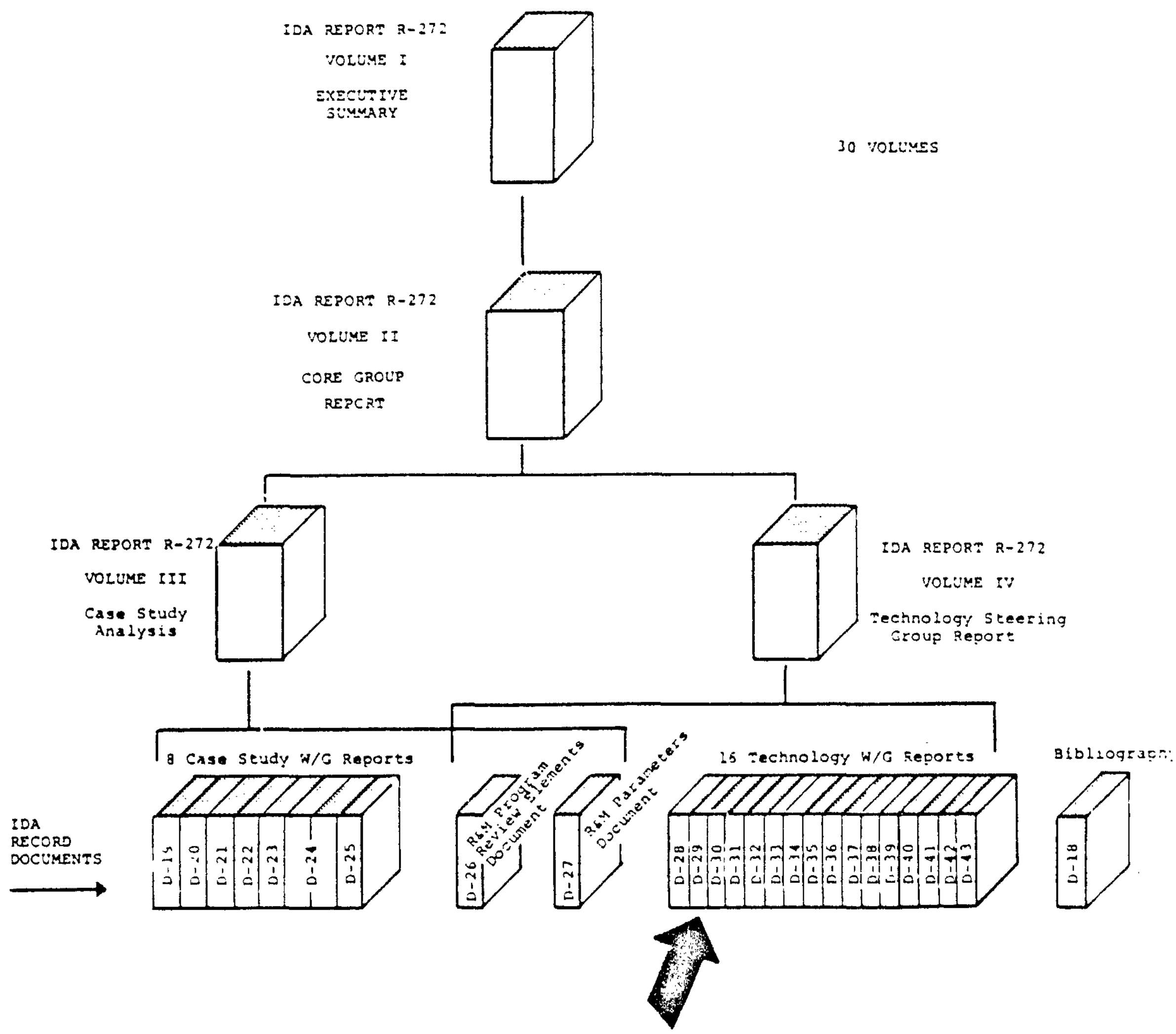
RELIABILITY AND MAINTAINABILITY STUDY

— REPORT STRUCTURE —



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PREFACE

As a result of the 1981 Defense Science Board Summer Study on Operational Readiness, Task Order T-2-126 was generated to look at potential steps toward improving the Material Readiness Posture of DoD (Short Title: R&M Study). This task order was structured to address the improvement of R&M and readiness through innovative program structuring and applications of new and advancing technology. Volume I summarizes the total study activity. Volume II integrates analysis relative to Volume III, program structuring aspects, and Volume IV, new and advancing technology aspects.

The objective of this study as defined by the task order is:

> "Identify and provide support for high payoff actions which the DoD can take to improve the military system design, development and support process so as to provide quantum improvement in R&M and readiness through innovative uses of advancing technology and program structure."

The scope of this study as defined by the task order is:

> To (1) identify high-payoff areas where the DoD could improve current system design, development program structure and system support policies, with the objective of enhancing peacetime availability of major weapons systems and the potential to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible, (2) assess the impact of advancing technology on the recommended approaches and guidelines, and (3) evaluate the potential and recommend strategies that might result in quantum increases in R&M or readiness through innovative uses of advancing technology.

The approach taken for the study was focused on producing meaningful implementable recommendations substantiated by quantitative data with implementation plans and vehicles to be provided where practical. To accomplish this, emphasis was placed upon the elucidation and integration of the expert knowledge and experience of engineers, developers, managers, testers and users involved with the complete acquisition cycle of weapons systems programs as well as upon supporting analysis. A search was conducted through major industrial companies, a director was selected and the following general plan was adopted.

General Study Plan

Vol. III	•	Select, analyze and review existing successful program
Vol. IV	•	Analyze and review related new and advanced technology
Vol. II	(•	Analyze and integrate review results
	(•	Develop, coordinate and refine new concepts
Vol. I	•	Present new concepts to DoD with implementation plan and recommendations for application.

The approach to implementing the plan was based on an executive council core group for organization, analysis, integration and continuity; making extensive use of working groups, heavy military and industry involvement and participation, and coordination and refinement through joint industry/service analysis and review. Overall study organization is shown in Fig. P-1.

The basic technology study approach was to build a foundation for analysis and to analyze areas of technology to surface: technology available today which might be applied more broadly; technology which requires demonstration to finalize and reduce risk; and technology which requires action today to provide reliable and maintainable systems in the future. Program structuring implications were also considered. Tools used to accomplish

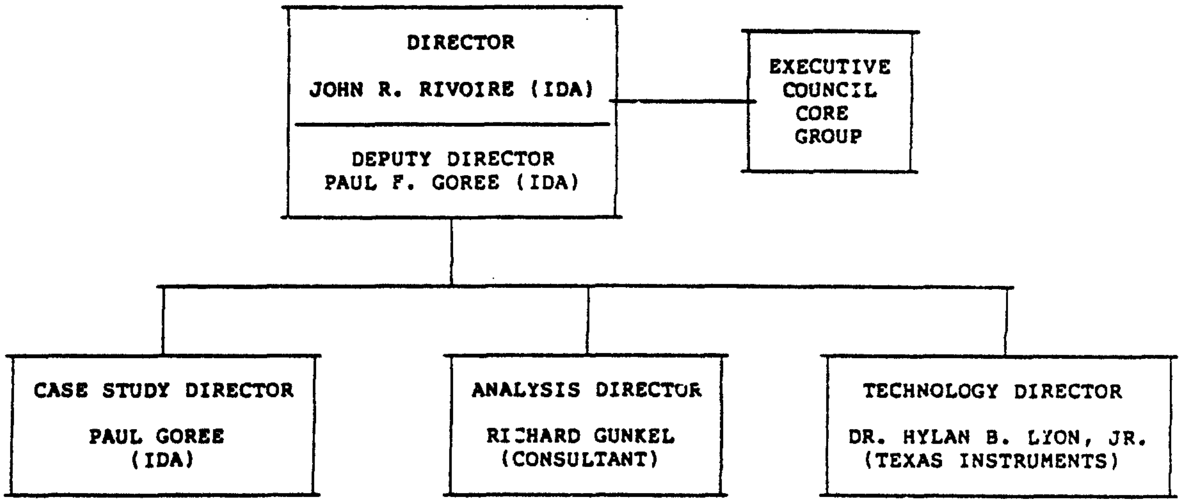

FIGURE P-1. Study Organization

this were existing documents, reports and study efforts such as the Militarily Critical Technologies List. To accomplish the technology studies, sixteen working groups were formed and the organization shown in Fig. P-2 was established.

This document records the activities and findings of the Technology Working Group for the specific technology as indicated in Fig. P-2. The views expressed within this document are those of the working group only. Publication of this document does not indicate endorsement by IDA, its staff, or its sponsoring agencies.

Without the detailed efforts, energies, patience and candidness of those intimately involved in the technologies studied, this technology study effort would not have been possible within the time and resources available.

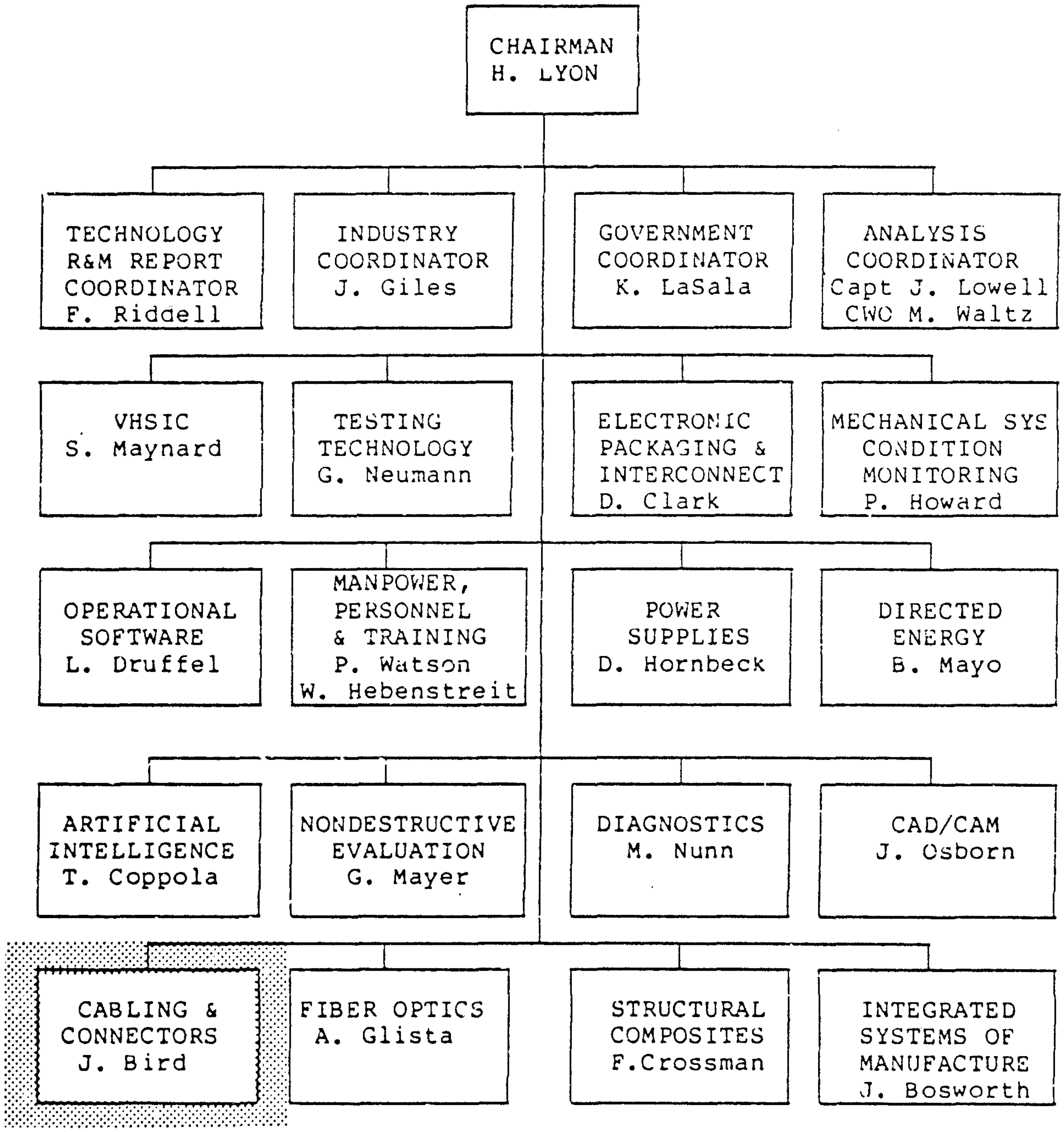

FIGURE P-2. Technology Study Organization

IDA/OSD R&M STUDY

CABLING AND CONNECTORS TECHNOLOGY

WORKING GROUP REPORT

Working Group Members - J.W. Bird
L. LaFornaea
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OVERVIEW

It is almost impossible to find electrical or electronic equipment anywhere in today's world that does not use one or more type/types of connectors. These connectors not only influence the system design but frequently determine whether a system is functionally and economically viable.

Historically, an electrical connector was generally considered only a hardware item and, as such, was often the last item considered in the design and packaging of a piece of electrical or electronic equipment. Requirements were unsophisticated and were met by a number of standard, off-the-shelf connectors. These were reasonably satisfactory for most early applications of electronic equipment, in which signal voltage and current levels were relatively high. Thus, the selection and application of connectors posed no real problems.

Power connectors and cable connectors for signals between associated pieces of equipment were the first requirements for easily removable connections. In many cases soldered connections and screw-type terminal boards were used to interconnect various subassemblies. With the rapid growth in the field of electronics, equipment became more complex, and more and more connectors were needed to interconnect electronic functions in a practical, modular form that was both manufacturable and maintainable. In today's packaging concepts, connectors have become a very vital link in forming or making up a complete electronic system, and as such, they are in fact a very important component part of that system, rather than merely another item of necessary hardware. Thus, as with any component part, connector requirements must be evaluated, and connectors must be selected just as carefully as are the other components before a package design is frozen, rather than after the fact when volumetric considerations can dictate a compromise connector selection based almost entirely on size alone,

which would be detrimental to reliability, or on the resultant need for "special" that could be overly costly. Consideration must be given to all electrical, mechanical, and environmental stresses to which the connector will be likely to be subjected in use, as well as to the compatibility of physical form and dimension with the intended packaging concept of the equipment in which it will be used.

The genesis connector has many species. These species/subdivisions are: Rack and Panel Connectors (See Figure 1). Strictly speaking, rack and panel connectors are connectors that have one-half, usually the female side, mounted into a panel or backplane.

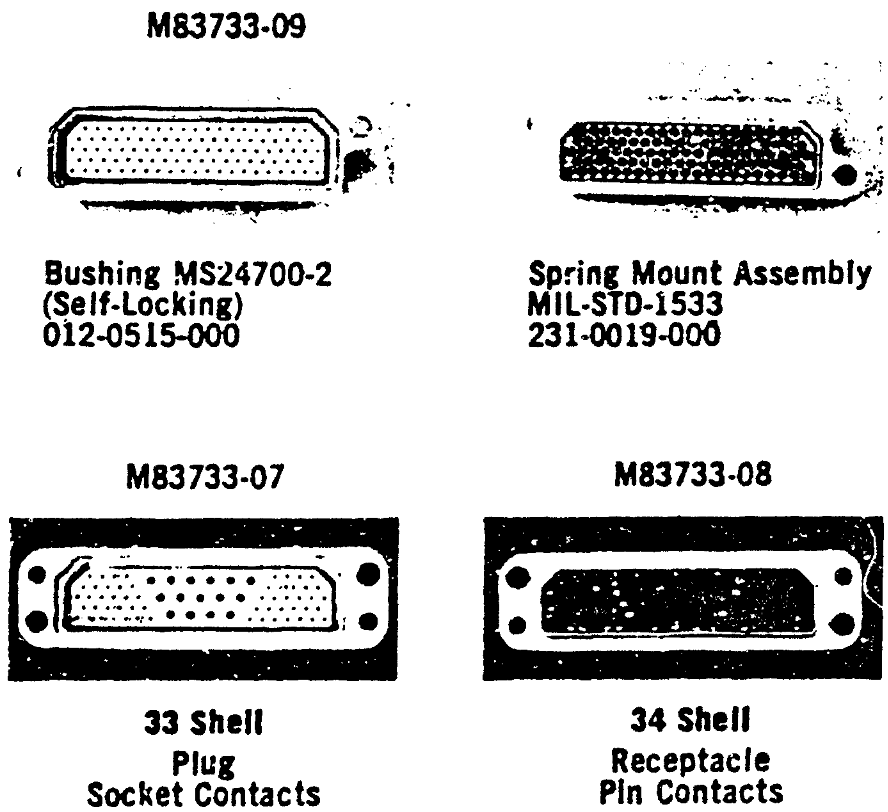

FIGURE 1

The other half is mounted on the face of the drawer or in a module in such a manner that when the drawer is slid into the rack, or the module is plugged in, the connector engages. Rack and panel connectors are generally considered to be rectangular multi-pin connectors, although round connectors can be and are used for rack and panel applications also. In a true rack and panel application the connector must be considered a precision component and the connector alignment and the connector mating characteristics must be carefully considered to ensure proper functioning of the equipment.

Printed circuit connectors are divided into two main types. The one-piece edge connector is a receptacle containing female contacts, and designed to receive the edge of the printed circuit board on which the male contacts are etched and printed. In the two-piece male and female connector, one piece, usually the male half, is attached to the printed circuit board to allow the two connector halves to mate, as do conventional connectors. A variation of the two-piece printed circuit connector is one in which the female contacts are contained in the conventional molding and the individual male contacts are fastened to the printed circuit board in such a fashion as to form the mating half of the connector.

The standard edge receptacle is available with single rows of contacts to mate with the contacts on one side only of the printed circuit board or with double rows of contacts to mate with individual contacts on both sides of the circuit board, thus allowing twice the contact density of the single row receptacle in the same length (Figure 2).

Two-piece printed circuit connectors. This family of connectors is, essentially, a variation of the familiar two-piece rack and panel connector. One piece, usually the female half, is mounted to a frame or back plane, and the other piece is mounted to the circuit board. This type of printed-circuit

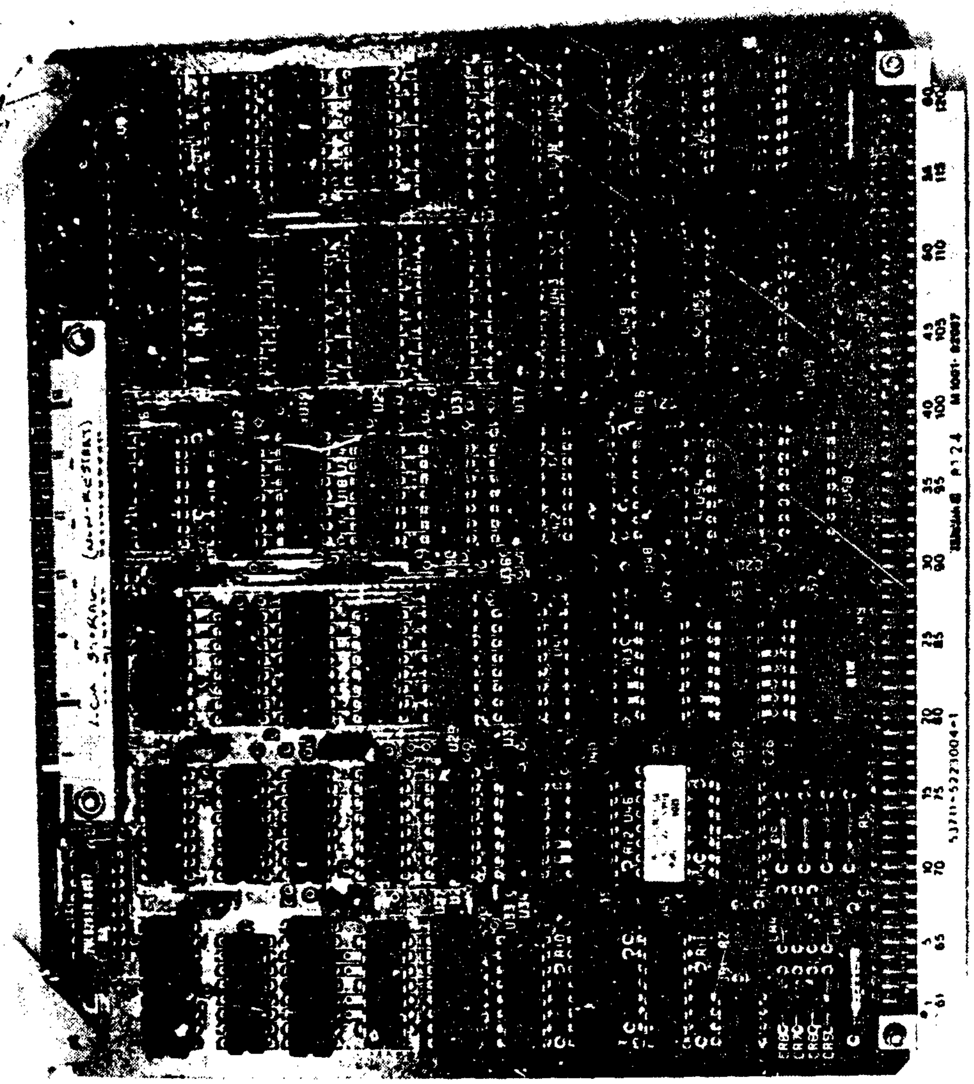

FIGURE 2

connector is generally more expensive, both initially and installed, than edge receptacles because there are two pieces rather than one, and one of the pieces must be affixed to the printed circuit board, usually by soldering. However, the advantage of this type of connector is that the contact mating material is controlled by a single manufacturer, as opposed to what is actually a joint effort between a connector manufacturer and the user with the edge type, thus reducing potential reliability problems that can be introduced in edge receptacle application. If the manufactured receptacle and printed circuit board are not totally compatible, in such applications where extreme vibration is anticipated, the two-piece connector would be desirable (Figure 3).

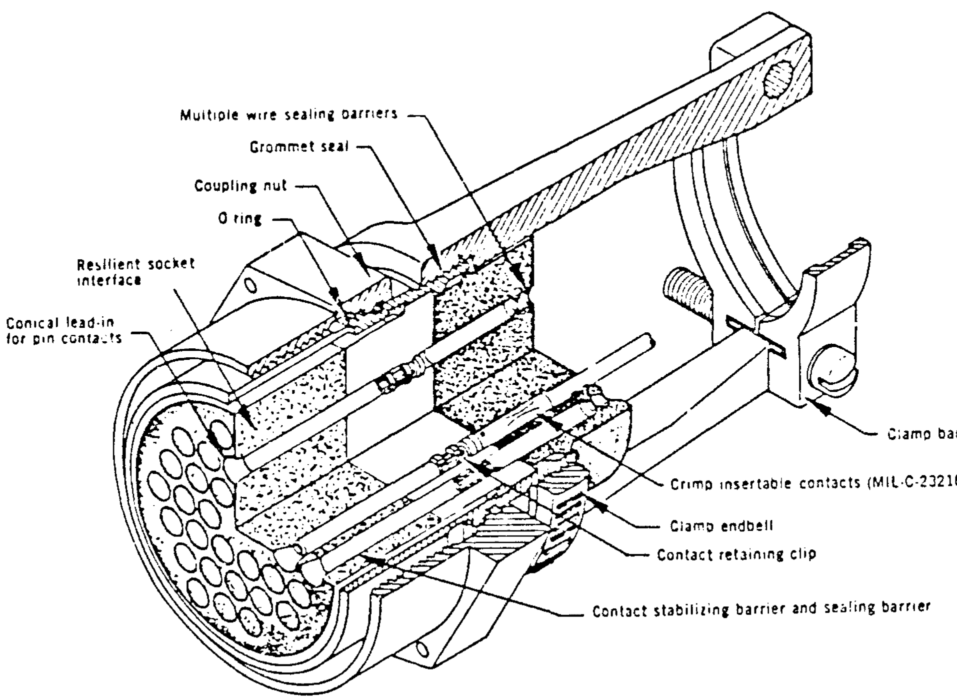

FIGURE 3

Cylinder Connectors. Cylindrical connectors are generally used on functional equipments that need relatively frequent disconnection for inspection, check-out, maintenance, or repair.

They are used primarily to connect cables together and to interconnect equipment "black boxes." The greatest usage, by far, is in military and aerospace applications, although they are also widely used commercially for interconnection between computer cabinets and associated peripheral equipment and in all types of communication equipment. Cylindrical connectors are basically rugged and, by the nature of their shape and construction, will withstand rough handling and generally hostile environments. There are many hundreds of types, sizes, contact and insert arrangements, polarizations, and associated hardware variations of cylindrical connectors. The very large majority of cylindrical connectors are designed and manufactured to the specifications of the several military specifications covering this family of connectors.

Coaxial Connectors. For the past 25 years, most coaxial connectors have been manufactured to conform to MIL specifications, with the possible exception of some of the microminiature ones recently developed. Continued requirements for different sizes, shapes, and electrical characteristics led to a confusing array of specifications that eventually covered over 15 types of coaxial connectors and a grand total of over 500 documents, specifications, and MS drawings to cover all the sizes, shapes, impedance characteristics, materials and variations. Mainly, these documents called out dimensional requirements, materials and overall electrical parameters rather than actual performance requirements and standard, reproducible test requirements. The result of this multitude of documents was twofold: 1. No particular technical competence was required to manufacture the connectors to the dimensional and material requirements of the MIL specifications and MS drawings, with the result that connector performance of supposedly identical connectors manufactured by several different manufacturers could vary greatly due largely to mechanical tolerances involved. 2. The dimensional specifications did not

permit the manufacturers to make design simplifications to improve the parts and/or reduce costs. The net outcome to the user was, in many instances, extreme confusion about what connector to use in a given application, and disappointment in performance of the selected parts. The situation became acute as performance requirements for advanced electronic equipment such as radar, microwave communications, data transmission systems, and aerospace applications became more and more critical. In 1960 the American Standards Association formed a committee to study the problem and to suggest corrective action. The result of the study and recommendations of the committee was a coordinated tri-service specification, MIL-C-39012, which is a general specification covering several types of coaxial (rf) connectors. This new specification specifies an rf connector by means of all applicable performance parameters, tested in an appropriate and consistent manner, and specifies only envelope and mating face dimensions for a given connector. The electrical requirements for connectors qualified to MIL-C-39012 include insulation resistance, dielectric withstanding voltage, rf high potential, contact resistance, rf leakage, voltage standing wave ratio (VSWR), and insertion loss. The mechanical parameters include engaging force, cable retention force, coupling mechanism force, mating characteristics, and contact durability. Physical and environmental requirements are also specified. In addition, this new specification requires rigorous qualification testing, with periodic requalification.

Tape Cable Connectors. Tape (flat flexible) cable was first introduced about 10 years ago and although its many advantages became apparent over the years, its usage has been relatively limited, in part, because of the fact that there were no easily applied, good, reliable connectors available for terminating it until the past two or three years. Another hindrance to both the use of the cable and the development of connectors for it was the lack of generally accepted guidelines or standards for cable,

thus making it difficult for the connector manufacturers to design connectors for the cable that would be more or less standard.

Finally, in 1963, the National Aerospace Standard 729 was introduced which, in cooperation with the Institute of Printed Circuits, became the basic standard for continuous, flat, flexible cable. Materials, conductor spacing, conductor sizes, and number of conductors were specified. making it possible for the connector industry, as well as the manufacturers of the flat cable, to develop various connector concepts that were compatible with the standard cables.

Plate Connectors. The plate connector is so named because it consists basically of a metal baseplate on which contact assemblies and/or connectors are precisely mounted in very accurately positioned holes located in a predetermined grid pattern. The principal advantage of this concept is that, without any special tooling, a plate connector can be designed to accommodate almost any conceivable combination of plug-in modules, cable connectors, printed-circuit boards, and patch cords. These can be keyed in a number of ways, including variations in group patterns, variations in terminal orientation, and the use of stand-off keys and washers. In addition, visual keying may be achieved by means of color variation in the plastic insulators used. Rather than a simple connector, the plate connector is, in fact, a packaging system with great flexibility. A major constraint upon this flexibility is that the contacts must necessarily be confined to one of the several grid systems for which tooling exists, both for the plate and for the contact assemblies. However, the fact that all the contacts are on a predetermined grid pattern makes possible the use of automatic machinery to wire the contact terminals as a back plane. Wire wrap and Termi-point are two of the most common and economical methods of wiring, although solder, weld, and crimp-type terminals are available.

All of the aforementioned sub-species/sub-divisions are

manufactured in standard, miniature, and micro-miniature sizes, plus a wide range of configurational variations. These variations are driven by specific mounting/use requirements such as: cable to cable, bulkhead mounting, rack and panel, termination direction, number of contacting elements, etc. These variations are further enhanced by the termination design requirements (i.e., the means of affixing contact to the conductor, the means of contact retention, and the means of securing one connector assembly to another.)

Contact Material. The choice for contact material has a direct bearing on all other connector design considerations and an important influence on the electrical characteristics of the connector (Figure 4). The contact is the heart of any connector, and thus it must function not only as an electrical conductor, but must be able to withstand adequately all the projected mechanical and environmental conditions to which the connector will be exposed in service. Some commonly used contact materials are: beryllium copper, spring brass, and low-leaded brass.

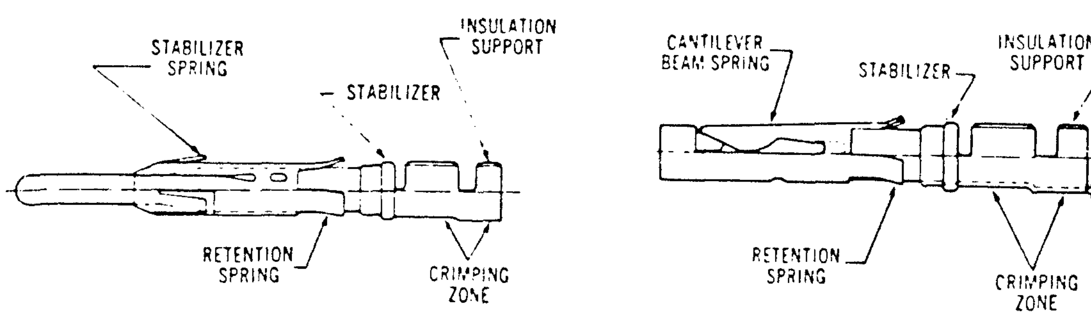

FIGURE 4

Plating of the basis metal of connector contacts is normally required to prevent deterioration of the mating surfaces of the contacts, mechanically or chemically. Such deterioration eventually results in the inability of the mated contacts to perform their required function in a given application. Cost per contact of a given connector can be greatly affected by the plating; however, so many variables affect plating that it is difficult to make meaningful comparisons. Variations in plating materials, plating thickness, contact shape, and combinations of all these parameters are all significant factors. Contact plating should be considered on an individual basis for a particular application, and it is recommended that the experience and technical know-how of the connector manufacturer be utilized in determining the plating to be used.

The two main problems to be considered are wear and chemical environment. The plating should be adequate to cover and protect the basis contact material in the "worst-case" conditions of both these factors. Hard gold plating on socket contacts and soft gold on pin contacts is used where numerous insertions and withdrawals are anticipated. This combination of hard and soft plating results in a burnishing action that improves wear resistance and also actually improves the contact resistance factor. An overplating of gold with an underplating of a less precious metal is often used for specific environments as an added protective factor in the event that the gold overplating wears through.

Connector Selection. It cannot be stressed too heavily that connectors are a vital part of an electrical or electronic system, for no printed-circuit board or black box can perform any better than the characteristics of the connector through which it is made into the system. Even in the simplest connector applications, consideration must be given to all the electrical, mechanical, and environmental stresses that are anticipated in end use. Also, physical form, size, and compatibility to the intended

package concept must be considered. No matter what the equipment may be, whether it be an electronic garage door opener, a radio, or an electronic computer for use in a small business, it must perform its intended function reliably.

Connector Reliability. The whole subject of reliability as applied to electrical connectors, as well as to all electrical and electronic components and extended into complete systems, is one that is discussed freely and authoritatively by many learned people but all too often on a strictly theoretical level rather than as a practical, applied science.

In the electronics industry, reliability has been defined in many ways by many people. The definition given here is a simple and easily understood statement of what reliability really is, as applied to components in a system. Reliability is the probability that a given device will perform without failure to a given set of requirements for a specified length of time.

Another generally overlooked contribution to connector reliability or unreliability is the handling of the connectors during installation and maintenance. Mishandling, physical damage (particularly to contact pins), dirt, improper or careless attachment of wire or cable, improper mounting, etc., can result in reliability problems with an otherwise normally good, reliable connector.

The following simple rules and suggestions should aid in the selection and application of connectors:

1. Unlike other components, a connector does not contribute to the function or characteristics of an electrical or electronic circuit. Its function is a mechanical one, to provide a means of engaging and disengaging electrical circuitry that provides energy or routes intelligence from one point to another. Therefore, of prime consideration is that it be of sound mechanical design and construction, and that all materials used as basis contact material, platings, insulating, and structural materials be

adequate and compatible with the physical and environmental stresses to which they will be subjected.

2. Be sure that connectors are properly mounted. If mounted in a panel or frame there must be sufficient rigidity so that any mechanical stresses on the mounting will not be transmitted to the connector. Proper float relationship between connector halves must be maintained. Make sure that wiring or cabling is properly dressed and supported so that it does not put undue strain on contacts (especially crimp/removable types), and also so that it does not inhibit connector float.

3. Connectors must be installed and serviced by trained, capable personnel. Mishandling, from installation and wiring through maintenance, is probably the greatest single cause of connector failure. Be sure that all terminations are properly made using proper tools and processes. Be sure that miscellaneous hardware items are properly applied.

CONNECTORS AND CABLING

The intended scope of this report is to define and quantify the major contributory causes of malfunctions/failures of cabling and connectors in weapon systems and to identify the constraints, if any, that will be created by the incorporation of new technology into future weapon systems:

Cable: A bound or sheathed group of mutually insulated and terminated conductors.

Connector: A device or a group of devices which join or fasten together, link, unite, establish communication between: intelligent information transmission lines and/or power distribution conductors.

Cables and connectors are integral elements of the electrical/electronic systems. This integration begins at the component level and continues throughout the system architecture. Conductors and their associated terminations form the distribution network for power, control and information signals essential to system performance. The operational/functional requirement diversity has driven the proliferation of different connector and conductor configurations. These variations are not limited to one type or class of network elements, but include all of the generic connector/conductor family.

The electrical/electronic technology has expanded at an exponential rate for many years. This rapid expansion has produced innumerable changes. These changes include different devices, (i.e., the transistor, integrated circuits, liquid crystal displays, etc.) reduction in size, an increase of operational frequency and an increase in complexity. It is the increase in complexity that has impacted reliability and maintainability most directly.

An example of this complexity and the reciprocal growth in the number of connectors and conductors is the launch sequencer unit of the MK-41 Vertical Launching System. This unit's major wiring harness is comprised of 3026 conductors of 14 different types/sizes, 54 different types of termination hardware, i.e., connecting elements and 10 types of connector insulated inserts. This harness does not include any of the printed wiring board connector assemblies, the line-replaceable unit's conductors or connector assemblies or any of the coaxial transmission elements. The total number of connector elements in this wiring subassembly exceeds 6060. The malfunction of any of these connector elements or the conductors could result in either marginal performance or non-operational status (Figure 5).

To further compound the reliability and maintainability aspect, the MK-41 System contains eight of the launch sequencers, eight motor control panels, one status panel, one 400-cycle and one 60-cycle power distribution unit, 24 power supply units, 8 damage control units, eight anti-icing panels, eight modular lighting junction boxes and one system lighting junction box. All of these "black boxes" are interconnected at various levels with one or more of 205 cable assemblies. Approximately 25 percent of these cable assemblies are 8 to 10 feet in length, while the remaining assemblies average 20 feet or more. Each assembly contains from 6 to 126 conductors with a system average of 25 conductors per cable assembly. The total number of connectors in the MK-41 system exceeds 500,000.

Throughout the maintenance community, cables and connectors are considered a major contributor to the non-operational status of current weapon systems. The Science Application Inc. Report 1-345-00-881-99, Contract NOOD19-80-C0094, quantifies the contribution at sixty percent for avionic systems and at thirty-three percent for aircraft.

The RCS-LOG(M)71117, PCN(A-G)26-009-MF-MGF, a monthly report,

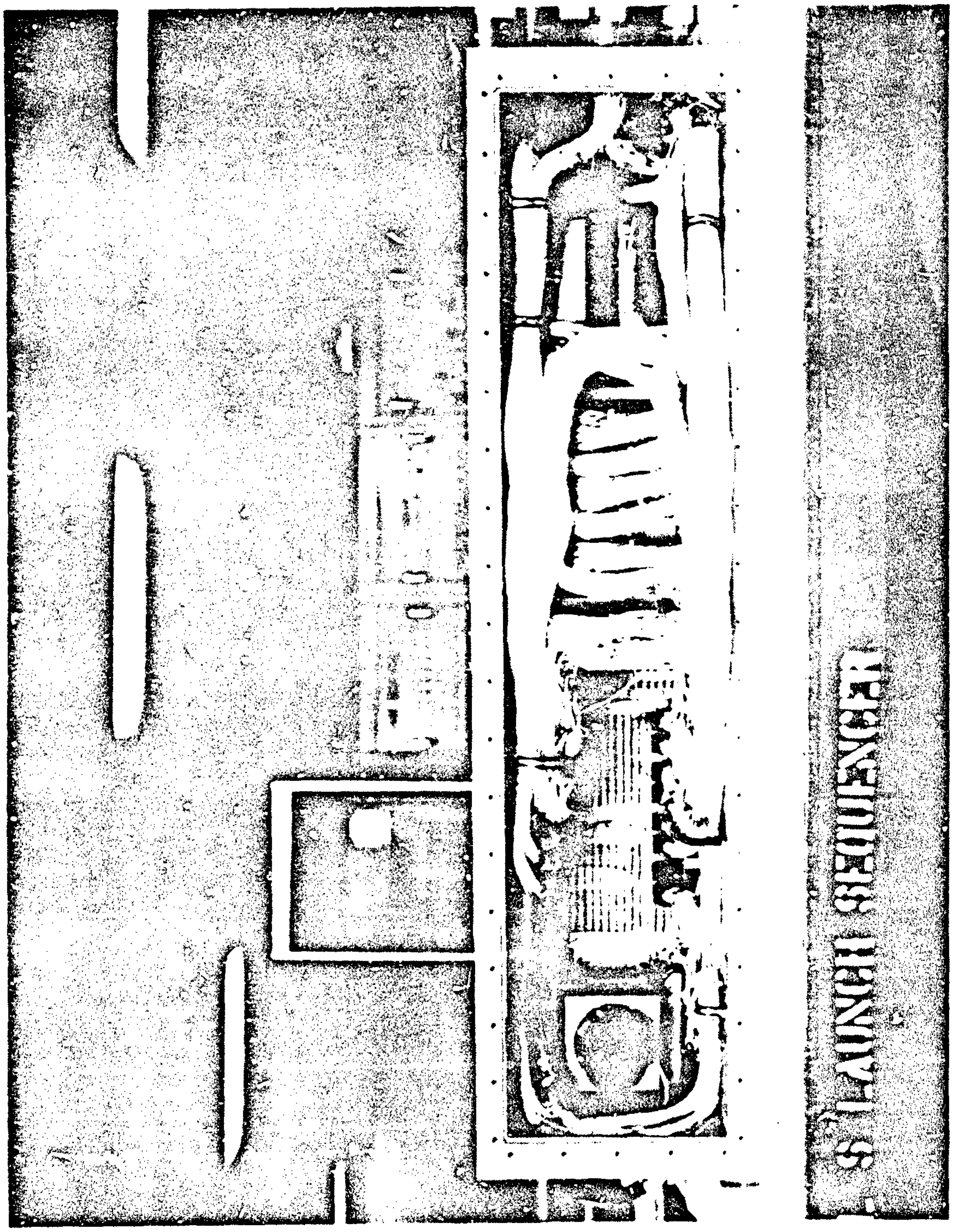

FIGURE 5

contains an average population density of specific connector and probable cable/buss failure of seven to ten percent. The investigation/reviews of the failure reporting documentation and discussion with operating maintenance personnel undertaken in support of this report in 1983 at Wright-Patterson AFB tend to support a failure quantification level of twelve to fourteen percent.

At this time there appears to be no consensus of the quantified level of contribution of cables and connectors to system failure, nor does one find a single source or collecting point for cable and connector failures.

Whereas various military and industrial groups are addressing standardization and design specifications and requirements, they lack centralized direction. Without central direction and an effective failure reporting system which is chartered to address the connector and cable failures, it becomes highly improbable that the appropriate corrective action will occur in a timely fashion.

However, certain general contributors to cable and connector failures can be defined. In descending order of contribution they are:

Attachment
Application
Abuse
Corrosion/Oxidization
Design Deficiency

Attachment. The probability of failure at the attachment interface of the conductor and connector element results from the non-standardized configuration of this termination zone and the process variations used to accomplish the joining.

At this interface there is:

- A change in material
- A configuration transition, this being controlled by the termination process

- A concentration of stress
- An increase in electrical resistivity

All of these factors are normally addressed during the design phase. Operational parametrics and reliability are also design constraints. However, these primarily are dependent on the termination process and the operator's skill. The common termination processes include soldering, crimping and insulation displacement. Each requires special equipment, controls and operator training.

These methods, when optimized, exhibit a high level of reliability, but manufacturing, tooling and the operator's skill level tolerances degrade this reliability. The transfer of conductor motion into this interface, which is essentially constrained or fixed, adds another factor to the degradation of the element's reliability. This is further exacerbated by the multitude of wire sizes and configurational requirements, i.e., solid and stranded wire, the type and size of the insulation material and the special forms, such as coaxial and printed circuit traces.

Application. Application failures have a variety of causes, the most apparent being the choice of a device/assembly not suited or designed for the environmental conditions encountered and failure to address the real operational life experiences of the device/assembly. A second source is the compromise of fit. This is the result of economics. There exist fifty-four wire sizes, each with its unique cross-section, current capability and construction variations, i.e., solid, 7-strand, etc. It was not considered economically sound to design a custom fit for each wire size so the wire/conductor termination zones are sized to accommodate a range of wire size. Fox example, AWG 22-24, AWG 24-28, AWG 28-30 are typical for open barrel connectors. However, due to the availability of a limited number of insert configurations, i.e., the insulated housing, the choice (mix) of particular contact

sizes may not be achievable, thus forcing a further compromise and again reducing the reliability.

Abuse. The abuse failures are human-induced. They begin at the assembly level and continue throughout the equipment's life-cycle. They range from improper seating of the connector element in the insulating housing to force-fitting of mated pairs, the dropping of the element/assembly into contaminating environment (i.e., mud, dust, water) to running over/walking on, all of which exceed the design intent and certainly contribute to the failure rate.

Corrosion/Oxidation. This failure mode is a long-term phenomenon and in connectors and cabling is generally exhibited as a degradation of performance rather than a step function failure.

Most metals, with the exception of the noble metals, such as gold, can be oxidized by atmospheric oxygen. It is the usual case, however, that water vapor must be present before any appreciable oxidation can take place. In a restricted sense, corrosion is considered to consist of the slow chemical and electromechanical reactions between metal and its environment.

The corrosive agents can be placed into four major groups. These are:

Oxygen and oxidants
Acidic materials
Salts
Alkalis

Corrosion attributable to oxygen appears to result from the mixing of oxygen with a thin film of liquid adjacent to the metallic surface, the transportation of oxygen through the film, and the subsequent reaction at the surface of the metal.

There are three principal categories of oxidizing agents which occur as air pollutants. These are: ozone, nitrogen oxides and nitric acid, and organic peroxide. Whereas many materials

are relatively resistant to attack by free oxygen, they are far less resistant to attack by such oxidants and peroxides. These agents dissolve in the surface film and thus convert metals into their oxides, which react readily with weak acid.

The acid components within the air are the results of various combustion processes associated with:

Sulfur dioxide and sulfurous acid
Sulfuric acid
Hydrogen sulfide
Hydrochloric acid
Carbon dioxide and carbonic acid

The major contributor of this group to atmospheric corrosion is sulfur dioxide, while carbon dioxide and carbonic acid play a significant role in acid decomposition.

It is common to consider that certain salts have a very corrosive action. This is true in respect to marine atmosphere vs. the urban, rural and tropical atmospheres. For example, ammonium sulfate and ammonium chloride, being salts of strong acids and a weak base, i.e., ammonium hydroxide, hydrolyze in water to yield to the respective acids. These salts then have a corrosive action which is due to the acid produced in hydrolysis.

Alkalis seldom occur as air pollutants except under industrial conditions. Nevertheless, this source of corrosion should not be overlooked. While a number of metals are resistant to acid attack, they have an amphoteric action and can react with alkalis. Aluminum and zinc are in this category and are subject to corrosive attacks by relatively weak alkalis.

Generally, metals are resistant to attack in dry air. Even in pure humid air, corrosion is slight. However, when air pollutants are present, the rate of corrosion will increase. The rate of the increase is dependent upon the humidity level and character of the pollutant. Such action may be grouped as follows:

Relative Humidity		Degree of Corrosion
Less than	60	None
More than	60	Slow but definite
	80	Decided increase
Greater than	80	Very high

It should be noted that particles of carbon, ammonium sulfate and silica in contact with or adhered to the metal surface cause a marked increase in corrosion. The presence of such hygroscopic particles enhances the adherence of liquids, and thus provides for electromechanical attack.

Design Deficiency. The final contributor to failure is design deficiency. Whereas the initial testing weeds out the major deficiencies there are certain characteristics which require long-term exposure to an environmental condition before they change the operational performance of the device. It is this type of failure which normally is identified first by the field but quantitatively contributes less than one percent to the reported failures.

To this list of contributors, the conductor-related modes must be added. These modes are:

- The loss or reduction of insulating characteristics of the dielectric covering of the conductor. This may be induced by aging, chemical attack, mechanical abrasion, perforation or excessive flexure.

- The loss or reduction of the conductor's ability to act as a transmission line. This condition may result from elongation due to installation methods, localized flexure due to vibration, excessive bend radii stress or the actual disjoining of the conductor by external force.

The introduction of new technology into weapon systems design will certainly engender change relative to the interconnecting systems elements. To what extent these changes will affect the current level of failure/non-operational status allocated to connectors and cabling is difficult to predict without specific knowledge of the application. It is possible, however, to identify, in general terms, the positive and negative factors of the most likely candidates for incorporation. These candidates, fiber optics and very high speed integrated circuits (VHSIC), will exacerbate some modes of failure, diminish others and add new modes to the list.

The fiber optics technology benefits over metal systems are:

- Larger bandwidth and small loss
- Smaller size and weight
- Lower material cost
- Lower system cost per channel
- Higher system channel capacity
- Electrical isolation of input and output data paths
- High immunity to electromagnetic interference (EMI)
- Near zero-level crosstalk and signal leakage

The drawbacks/negative aspects of fiber optics in general are:

- Need for more precise control of production parameters
- Difficulty of joining individual fiber segments
- Limited life of light sources and associated system reliability
- Need for fiber protection in order to allow for installation and maintenance treatment

Many of the drawbacks/negatives of this technology will

disappear in the near term as the result of research and development efforts. However, relative to maintainability and reliability, the increased sensitivity to handling abuse, particularly at the transmission interface and the novelty of the connector configurations must be considered long-term. Another element of this technology's introduction that must be considered is the special training requirements.

The fiber optics positive contributions will be the reduction in the types of conductor sizes and configurations, a reduction in the number and types of interconnections and the reduction of physical size and weight of the cable assemblies. The negative contributory factors are the increased sensitivity to handling abuse, the introduction of new and untried connector configurations and the need for special training in the care and maintenance of these system elements. A typical fiber optics connector is shown in Figure 6.

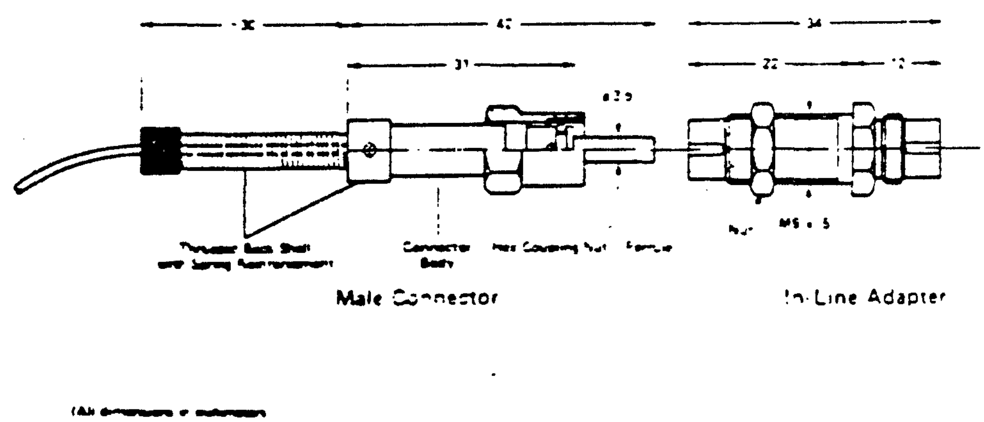

FIGURE 6

At this point in the development cycle, VHSIC technology lacks a definitive statement of configurational and electrical operating parameters. Therefore, the impact of this technology on connectors and cabling is speculative.

On the positive side, it is hypothesized that this technology will allow, via new processor architecture and the subsequent

reconfiguration of the electronic subsystems, a substantial reduction in the number of intra- and inter-subsystems connections. If a current operational system and its associated architecture were duplicated, using VHSIC technology, this may be true, but the availability of a much larger number of processing circuits may negate this potential. In all probability, this increase in processing circuitry and the increase in the operational speed will be utilized to expand the self-diagnostic and other non-primal system functions. If so, then the number of input/output interconnections will increase and minimize/exceed the original saving.

The brass board assemblies of the six VHSIC prime contractors and their subcontractors consume 50 to 1000 watts per system, with a single board average power consumption of 50 watts. A single board may contain 4 to 60 VHSIC CHIPS. The packaging approach of the chip carriers varies. Texas Instruments uses JEDEC type C leadless chip carrier, Honeywell 180 pads, Hughes, the leaded flatpack w/148 beads, Westinghouse, a leaded chip carrier 120 to 220 pin.

Based on the prime contractor's brass board systems, two potential areas of concern can be identified. These are the conditioned power requirement distribution and the higher operational speed off-chip clock rate of 25 MHz. The brass board systems of the six prime contractors consume 50 to 1000 watts, with a single printed wiring board's average consumption of 50 watts. Assuming that the operating voltage is 3.3 volts, each board must be capable of handling a current flow of 15 amperes. The majority of the in-use/available card connector assemblies are designed with a 3 ampere/pin configuration which mandates a multiple pin allocation of 12 pins per connector assembly if the available configurations are used. This, coupled with the input/output contact requirements of 200 to 300, places a severe

limitation on the packaging configuration, i.e., size and shape of PWB's, backplane, card cage, etc. The additional current flow will also affect the conductors and the allowable resistance of the conductor/connector interface.

The higher off-chip operating frequency, the lower signal level and the higher current demands of this technology will require new connector design. It will be essential to these new designs that the electrical parametrics, i.e., impedance matching, EMI shielding, low contact resistance, etc., and the increased input/output circuit requirements be established as design goals/ standards to assure reliability and ease of maintenance.

It is both fortuitous and aggravating that these failure sources are not mutually exclusive--fortuitous in the sense that the correction or control of one or more of the failure modes would possibly correct or minimize another mode--aggravating in the sense that it is very difficult to define or pinpoint the exact catalyst to the failure.

Obviously, given the number of connector/cable elements within the current weapons systems and the multitude of contributors to failure, it is not possible to reduce this reliability dilemma to zero; however, a major reduction is possible.

To achieve this reduction it is essential that the following action/actions be undertaken. These are:

1. Fund a special study of the connector and cabling failure. The charter of this study is to address the collection and analysis of data which will validate, quantify and define the modes and catalysis of connector and cable failure. This charter should include the identification of corrective action/actions required and the generation of a plan to accomplish these tasks.

2. Fund a research and development effort to evaluate the means

of termination relative to the VHSIC and fiber optics requirements.

Every weapon system and communication network, both present and future, rely on the connectors and cabling for the ability to operate. The improvement in system readiness and the savings in terms of personnel and dollars elevate the actions suggested from desirable to mandatory.

Development of new contacts, plating processes and new connector configurations have historically been market driven and corporately funded. Therefore, the potential return on investment, the manufacturer's normal market and manufacturing expertise have controlled the direction and sources of new connecting devices.

It would appear that if the development of new connecting devices and their availability consistent with the application of new technology incorporation within the weapon systems is to be realized, an incentive must be created. This incentive could be in the following form:

- Produce a Statement of Work. This would contain the desired mechanical and electrical requirements.
- Request a technical proposal from multiple sources.
- Fund and award a development program to a minimum of three of the technical proposal respondents.
- Review and test the configurations of the development phase.
- Fund and award an initial production contract.

The cost of this approach is variable; however, it could be a fixed cost or a matched funded program, i.e., 50 percent from the government and 50 percent from the selected participants.